REMARKS

This Preliminary Amendment cancels, without prejudice, claims 1 to 8 in the underlying PCT Application No. PCT/DE03/03917 and adds new claims 9 to 25. The new claims, inter alia, conform the claims to United States Patent and Trademark Office rules and does not add any new matter to the application.

In accordance with 37 C.F.R. § 1.125(b), the Substitute Specification (including the Abstract) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to United States Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. §§ 1.121(b)(3)(ii) and 1.125(c), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/DE03/03917 includes an International Search Report, dated August 23, 2004, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

The underlying PCT Application No. PCT/DE03/03917 also includes an International Preliminary Examination Report, dated January 24, 2005. A copy of the International Preliminary Examination Report is included herewith.

It is respectfully submitted that the subject matter of the present application is new, non-obvious and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully submitted,

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PROCESS FOR THE PRODUCTION OF HEAT EXCHANGER TUBES CONSISTING OF HALF-TUBES OR TUBES, FOR RECUPERATIVE WASTE GAS HEAT EXCHANGERS

FIELD OF THE INVENTION

The present invention relates to a process for the production of half-tubes or tubes of a metallic, high-temperature-resistant material with a plurality of openings passing through their surface, for the fabrication of heat exchanger tubes for recuperative waste gas heat exchangers, as well as half-tubes/tubes produced by this process.

BACKGROUND INFORMATION

As is ~~known~~ **conventional**, the recuperative waste gas heat exchangers used in gas turbine plants ~~comprise~~ **include**, in addition to a heat exchanger housing, ~~basically~~ a distributor tube for feeding the "cold" air conveyed from a compressor into a so-called cross-counterflow matrix through which hot turbine waste gas flows, and a collecting tube for passing the now heated-up "hot" compressor air to a suitable consumer, for example, the combustion chamber of the gas turbine plant. For ~~the sake of~~ simplicity, the distributor tube as well as the collecting tube will hereinafter also be referred to as heat exchanger tube.

The feeding of the air from the distributor tube into the cross-counterflow matrix and the discharge of the air from the cross-counterflow matrix into the collecting tube is effected by a plurality of openings made in the surface of the heat exchanger tubes.

The cross-counterflow matrix ~~comprises in turn~~ **includes** a plurality of elliptical lancets or small tubes assembled to form a tubular bundle. The tubular bundle is arranged

laterally and protruding in a U-shaped manner on the heat exchanger tubes arranged in parallel, the ends of each small tube of the tubular bundle corresponding in each case to an opening made in the surface of the heat exchanger tubes. In order to be able to achieve the desired throughput, a plurality of lancets and accordingly a plurality of openings/holes are necessary in the surface of the heat exchanger tubes.

The heat exchanger tubes consisting of a high-temperature-resistant material have ~~up to now~~ been assembled from forged half-tubes. The joining of two half-tubes to form a heat exchanger tube is effected by welding, and the attachment of the lancets to the heat exchanger tubes is effected by ~~means of~~ high-temperature soldering.

According to a typical ~~embodiment~~ of a half-tube of length 500 mm and radius 62.5 mm, rows of holes each ~~comprising~~ **<u>including</u>** 184 openings are provided on 19 circumferential positions, so that per half-tube a total of 3,496 openings are formed in the surface. For the production of the heat exchanger tubes of a recuperative waste gas heat exchanger from half-tubes, 4 x 3,496 = 13,984 holes/openings are therefore necessary in the surface of the half-tubes.

The formation of such a large number of openings in the surface of the forged half-tubes proves to be extremely cost-intensive and time-consuming.

The formation of the openings in the surface of the half-tubes has ~~up to now~~ therefore been achieved by spark erosion (EDM = electrodischarge machining). EDM is a ~~known~~ **<u>conventional</u>** method for producing holes or other openings in metals. The principle of the method, namely the thermal abrasion of small volumes by the high power density of a locally penetrating arc

in the liquid dielectric acting on the anode (workpiece), involves a melting of the material in microscopic dimensions.

Apart from the high cost, the EDM process has a further disadvantage. ~~On account of~~ **Due to** the process-dependent procedure involved in the forming of the openings in the surface of the heat exchanger tubes re-solidified layers, the so-called recast layers, are formed in the region of the perforation walls on the workpieces. These layers have to be removed before the high-temperature soldering to be carried out subsequently for soldering the lancets into the half-tubes, which proves to be a disadvantage and is complicated. The narrow soldering gaps and small tolerances (± 0.05 mm) required for the high-temperature soldering often cannot be achieved with existing recast layers for economic reasons (a slow fine processing stage is necessary).

Electrochemical processing (ECM = electrochemical machining) is another option for forming the openings in the surface of the half-tubes. This method is costly however in terms of installation and tooling, and has capital-intensive equipment costs.

Also, the electrolyte in this process is typically an oxidizing agent, for example, sodium nitrate or sodium chloride, which constitutes a health and security risk, and the by-products of the process are classified as toxic waste.

To summarize, this means that the formation of the openings in the surface of the forged half-tubes is a high-risk operation in terms of technology, time and cost in the production of the overall recuperative waste gas heat exchanger.

SUMMARY

~~The object~~ **An example embodiment** of the **present** invention ~~is to remedy this situation by means of~~ **may provide** a process for the production of ~~such~~ half-tubes or tubes of a metallic, high-temperature-resistant material with a plurality of openings passing through their surface, without the disadvantages of the processes **previously** employed ~~up to now~~.

~~This object is achieved according~~ **According** to **an example embodiment of** the **present** invention**,** ~~in that the~~ half-tubes or tubes ~~are~~ **may be** produced as high-precision casting parts by employing a precision casting process.

Such a precision casting process ~~has the advantage~~ **may provide** that it combines a high reproducibility with consistently high quality and low production costs.

In order to avoid reactions between the melt and ambient gases such as oxygen, nitrogen or hydrogen, at least the casting of the melt in the mold shell ~~is carried out~~ **may be performed** in the absence of reactive gases, ~~in particular~~ **e.g.,** *in vacuo*, in an inert gas atmosphere ~~or the like~~**, etc**.

In order that also narrow cross-sections and fine contours ~~can~~ **may** "run out" cleanly, the casting of the melt in hot mold shells ~~is carried out~~ **may be performed** *in vacuo* or under an excess pressure of inert gas.

A nickel-based alloy, ~~in particular~~ **e.g.,** IN 625, ~~is preferably~~ **may be** used as high-temperature-resistant material for the precision casting process.

According to ~~a preferred~~ **an example** embodiment of the half-tubes or tubes produced according to the process, the openings passing through the surface **may** have an elliptical shape. The

radius of the half-tubes/tubes ~~is~~ **may be** 62.5 or 37.5 mm, and the length of the half-tubes ~~is~~ **may be** 500 mm or 750-900 mm.

The use ~~according to the invention~~ of a precision casting process ~~known per se~~ for the production of heat-exchanger tubes from half-tubes or tubes ~~permits for the first time~~ **may provide for** an inexpensive, quick and qualitatively high-grade production of such tube components.

~~The~~ **An example embodiment of the present** invention is described in more detail ~~hereinafter with the aid of an example of implementation illustrated more or less diagrammatically in the drawings, in which:~~ **below with reference to the appended Figures.**

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 ~~shows~~ **illustrates** the basic structure of a recuperative waste gas heat exchanger[[,]].

Fig. 2 is a detailed view of a heat-exchanger tube~~, and~~.

Fig. 3 ~~shows~~ **illustrates** the assembly of the heat-exchanger tube ~~according to~~ **illustrated in** Fig. 2 from half-tubes.

DETAILED DESCRIPTION

A recuperative waste gas heat exchanger of a gas turbine plant ~~(not shown here)~~, identified overall in Fig. 1 by the reference numeral 10, ~~essentially comprises~~ **includes** a distributor tube 12, a collecting tube 14 arranged parallel thereto, as well as a cross-counterflow matrix 16 protruding laterally thereto in a U-shape. For ~~the sake of~~ simplicity, the distributor tube 12 and collecting tube 14 are identified hereinafter as heat exchanger tubes.

From the cross-sectional view of the cross-counterflow matrix 16 ~~shown~~ **illustrated** in the bottom left-hand corner of Fig. 1, it can be seen that the cross-counterflow matrix 16 ~~comprises~~ **includes** a plurality of elliptical small tubes or lancets 18. The lancets 18 are in each case secured to the distributor tube 12 and collecting tube 14. They correspond to the openings/holes 22, not visible in this ~~representation~~ **view**, made for this purpose in the surface of the distributor tube 12 and the collecting tube 14 (cf. Fig. 2).

The mode of operation of the recuperative waste gas heat exchanger described hereinbefore is as follows:

Cold compressed air is fed from a compressor in the direction of the arrow D to the distributor tube 12. The cold compressed air flows from the distributor tube 12 through the openings/holes made in the surface into the laterally protruding, U-shaped cross-counterflow matrix 16. The cold compressor air is heated up by the circulating flow of the hot turbine waste gas H through the cross-counterflow matrix 16. After flowing through the cross-counterflow matrix 16 and entering the collecting tube 14, the now hot air is fed in the direction of the arrow D′ to a suitable consumer, e.g. the combustion chamber.

Fig. 2 ~~shows~~ **illustrates** on an enlarged scale a detailed view of a perforated heat exchanger tube 12/14 of the recuperative waste gas heat exchanger 10. The heat exchanger tube 12/14 has a plurality of openings 22 passing through its surface 20. The openings 22 are elliptical in shape. Of this large number of openings 22 in the surface 20, for ~~the sake of~~ clarity, only a few of the openings 22 passing through the surface 20 of the heat exchanger tube 12/14 are ~~shown here~~ **illustrated**. For ~~the sake of~~ completeness, it may however be mentioned that 184 rows of holes, i.e., 3,496 openings 22, are provided per

half-tube of dimensions 500 mm in length and radius 62.5 mm. A total of 2 x 3,496 = 6,992 openings 22 passing through the surface 20 are thus produced per heat exchanger tube 12/14.

In this example, the heat exchanger tube 12/14 is, as ~~shown~~ **illustrated** in Fig. 3, assembled from a first half-tube 24 and a second half-tube 26. The joining of the two half-tubes 24, 26 is ~~carried out~~ **performed** by fusion welding, and the installation of the lancets ~~is~~ **may be** performed in a ~~known~~ **conventional** manner by ~~means of~~ high temperature soldering.

The production of the half-tubes 24, 26 by ~~means of~~ a precision casting method ~~known per se will now be~~ **is** described in detail, in which the process steps -- with the exception of the assembly of the half-tubes -- apply in the same ~~way~~ **manner** also to the production of a tube, i.e., a complete tube.

To this end, in a first process step a fine-structured, dimensionally accurate model of the half-tubes 24, 26 destroyable by heating, including the openings 22 passing through the surface 20, is first of all produced. Wax is used as the model material for this purpose.

The wax model including the wax gate system receives a mold shell by immersion in ceramic coating compositions followed by sanding with casting shell ceramics material. In order to ensure the stability of the mold shell, the automated process of immersion followed by sanding is repeated several times.

After the model has been melted, ~~preferably~~ **e.g.,** in an autoclave using superheated steam, the single-piece mold shells that are thereby formed are fired, thereby acquiring their fire resistance. This is followed by the casting of the melt into hot mold shells by employing a vacuum or under excess pressure of an inert gas.

In this ~~way~~ **manner,** it ~~is~~ **may be** ensured that also the narrow cross-sections between two openings 22 in the surface 20 of a half-tube 24, 26 "run out" cleanly. The melting and casting of the half-tube material is ~~carried out~~ **performed** under a high vacuum. A nickel-based alloy with the standard reference IN 625 (INCONEL) is used as material.

The cast half-tubes 24, 26 ~~should~~ **may** then be cleaned and trimmed, in which connection the sprues ~~should~~ **may** also be removed. For the fabrication of the half-tubes 24, 26**,** a post-treatment of the openings 22 passing through the surface 20 ~~should~~ **may** if necessary also be ~~carried out~~ **performed** in a last workstage by blasting with erosive abrasives or by a "facing operation" by ~~means of~~ EDM (electrodischarge machining). Because of the high quality and tight tolerances of the precision casting method that is used, only a short processing time ~~is~~ **may be** required for this purpose. The recast layers hitherto formed by producing the openings by ~~means of~~ EDM ~~can~~ **may** be greatly minimized and therefore disregarded, since they ~~are~~ **may be** negligibly thin and small as a result of the short processing time.

The assembly of two such half-tubes 24, 26 to form a heat exchanger tube 12/14 ~~is carried out~~ **may be performed** by a **conventional** fusion welding process~~, which is likewise known~~. The introduction of the lancets made of IN 625 into the elliptical perforations is ~~carried out~~ **performed** by a highly automated assembly and soldering operation with soldering paste by ~~means of~~ vacuum high-temperature soldering.

~~Abstract~~

ABSTRACT

~~The invention relates to~~ **In** a process for the production of half-tubes ~~(24, 26)~~ or tubes of a recuperative waste gas heat exchanger ~~(10)~~ using a precision casting process, ~~in which~~ the half-tubes ~~(24, 26)~~ or tubes consisting of a high-temperature-resistant metallic material have a plurality of elliptical openings ~~(22)~~ passing through their surface ~~(20)~~.

~~Fig. 3~~